EPA United States Environmental Protection Agency **Superfund**

The Data are current as of March 2001

Radionuclides and PRGs You Selected:

NOTE: If this page is too wide to print, try selecting a smaller font or printing in landscape mode.
WARNING: The Base Product product with which Session Manager is associated will expire within 30 days. Please contact your to have it renewed. WARNING: The Base Product product with which Program /web/prod/cgi-bin/epa-prgs/rad_0105.sas is assoc Please contact your SAS installation representative to have it renewed.

Radionuclide	Agricultural Soil (pCi /g)	Agricultural Soil (mg/kg)	Fish Ingestion (pCi /g)	Fish Ingestion (mg/kg)	Outdoor Worker Soil (pCi /g)	Outdoor Worker Soil (mg/kg)	Residential Soil (pCi /g)	Residential Soil (mg/kg)
Ra-226+D decaychain	8.07E-04	8.17E-10	3.42E-03	3.47E-09	2.48E-02	2.51E-08	9.33E-03	9.45E-09

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URL: http://stuart.ornl.gov/
This page was last updated on: August 21, 2001
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EPA United States Environmental Protection Agency **Superfund**

SELECTION:

Your **Analytes/CAS numbers** are:
Ra-226+D
Your **PRGs** are
Residential Soil
Outdoor Worker Soil
Indoor Worker Soil
Tap Water
Fish Ingestion
Soil to Ground Water
Agricultural Soil
Your **Units** are
pCi
Default Parameters
Each PRG you have selected is given below along with the applicable Equations and its associated Default Parameters. For each equation, the default values will be used unless you enter a different value.

Particulate Emission Factor

(needed for Residential Soil, Agricultural Soil, Outdoor Worker Soil, and/or Indoor Worker Soil)

$$PEF = Q/C * \frac{3{,}600}{0.036 * (1 - V) * (U_m / U_t)^3 * F(x)}$$

Minneapolis (V)	City (Climatic Zone)
0.5	Surface (acres)
93.77	Q/C (inverse of the mean conc. at the center of a 0.5-acre-square source) g/m^2-s per k g/m^3
0.5	V (fraction of vegetative cover) unitless
4.69	U_m (mean annual windspeed) m/s
11.32	U_t (equivalent threshold value of windspeed at 7m) m/s
0.194	F(x) (function dependent on U_m/U_t) unitless

NOTES:

1. PEF (particulate emission factor) m^3/kg. Default is 1.36x10^9
2. The Surface Area and City/Climate Zone are used to look up a Q/C. Q/C is the inverse of mean concentration at center of a 0.5 acre-square source (g/m^2-s per kg/m^3). Pick the city with the most similar climatic conditions (map).
3. The F(x) function is derived using Cowherd et al. (1985)

K_d values from Technical Background Document.

(Needed for Agricultural Soil and/or Soil to Ground Water.)

Americium	8.2	Cadmium	2.7	Carbon	0.8	Cerium	35	Cesium	10
Cobalt	0.1	Curium	86	Hydrogen	0	Iodine	0.03	Iron	3.1
Lead	6	Manganese	4.9	Neptunium	0.1	Nickel	34	Plutonium	5
Radium	3	Radon	0	Ruthenium	5	Silver	2.7	Strontium	1
Technetium	0.007	Thorium	20	Uranium	0.4	Zinc	0.1		

User-provided site-specific K_d values.

Actinium		Antimony		Bismuth		Chlorine		Europium	
Gadolinium		Niobium		Potassium		Promethium		Protactinium	
Samarium		Sodium		Thallium					

Residential Soil

Radionuclide Contaminants in Soil

$$C_{(pCi/g)} = \frac{TR \times t \times \lambda}{ED \times (1 - e^{-\lambda t}) \times \left[\left(SF_s \times IR_s \times 10^{-3}(g/mg) \times EF \right) + \left(SF_i \times IR_i \times \frac{10^3(g/kg)}{PEF} \times EF \times \left[ET_o + (ET_i \times DF_i) \right] \right) + \left(SF_e \times \frac{EF}{365(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF) \right] \right) + \left(SF_p \times (CR_f + CR_v) \times 10^3(g/kg) \times TF_p \times CPF \right) \right]}$$

Where:

$$IR_s = \frac{ED_c \times IR_c + ED_a \times IR_a}{ED}$$

$$IR_i = \frac{ED_c \times IRA_c + ED_a \times IRA_a}{ED}$$

$$CR_v = \frac{ED_c \times CR_{vc} + ED_a \times CR_{va}}{ED}$$

$$CR_f = \frac{ED_c \times CR_{fc} + ED_a \times CR_{fa}}{ED}$$

1.0E-6 TR (target risk) unitless	30 t (time of exposure) yr
30 ED (exposure duration, $ED_c + ED_a$) yr	350 EF (exposure frequency) d/yr
0.073 ET_o (exposure time fraction, outdoor) unitless	0.683 ET_i (exposure time fraction, indoor) unitless
0.4 DF_i (indoor dilution factor) unitless	0.9 ACF (area correction factor) unitless
0.4 GSF (gamma shielding factor) unitless	0.25 CPF (contaminated plant fraction) unitless
6 ED_c (exposure duration, child) yr	24 ED_a (exposure duration, adult) yr
200 IR_c (soil intake rate, child) mg/day	100 IR_a (soil intake rate, adult) mg/day
10 IRA_c (inhalation rate, child) m^3/day	20 IRA_a (inhalation rate, adult) m^3/day
40.2 CR_{fc} (fruit consumption rate, child) kg/yr	153.1 CR_{fa} (fruit consumption rate, adult) kg/yr
28 CR_{vc} (vegetable consumption rate, child) kg/yr	79.6 CR_{va} (vegetable consumption rate, adult) kg/yr

NOTES:

1. SF_s=soil ingestion slope factor (Risk/pCi). radionuclide-specific
2. SF_i=inhalation slope factor (Risk/pCi). radionuclide-specific
3. SF_e=external exposure slope factor (Risk/yr per pCi/g). radionuclide-specific
4. SF_p=food ingestion slope factor (Risk/pCi). radionuclide-specific
5. IR_s=age-adjusted ingestion rate (mg/day).
6. IR_i=age-adjusted inhalation rate (m^3/day).
7. CR_f=age-adjusted fruit consumption rate (kg/yr).
8. CR_v=age-adjusted vegetable consumption rate (kg/yr).
9. PEF=particulate emission factor (m^3/kg).
10. TF_p=soil-to-plant transfer factor. radionuclide-specific
11. λ = Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
12. The curie (Ci), the customary unit of activity, is equal to 3.7×10^{10} nuclear transformations per second.

1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Agricultural Soil

Radionuclide Contaminants in Agricultural Products

$$C_{(pCi/g)} = \frac{TR \times t \times \lambda}{ED_r \times \left(1 - e^{-\lambda t}\right) \times \left[ING_s + INH_s + EXT_s + PROD + FISH + MEAT + MILK\right]}$$

Where:

$$ING_{s(g/pCi-yr)} = IR_s \times EF \times SF_s \times 10^{-3}(g/mg)$$

$$EXT_{s(g/pCi-yr)} = \frac{EF}{365\ d/yr} \times ACF \times \left[ET_o + \left(ET_i \times GSF\right)\right] \times SF_s$$

$$INH_{s(g/pCi-yr)} = IR_i \times EF \times \left[ET_o + \left(ET_i \times DF_i\right)\right] \times SF_i \times \frac{10^3(g/kg)}{PEF}$$

$$PROD_{(g/pCi-yr)} = \left(CR_f + CR_v\right) \times TF_p \times CPF \times SF_f \times 10^3(g/kg)$$

$$FISH_{(g/pCi-yr)} = IR_f \times SF_f \times 10^3(g/kg)$$

$$MEAT_{(g/pCi-yr)} = \left(IR_b + IR_p\right) \times \left(\left(TF_b \times FI_b \times TF_p\right) + \left(TF_b \times FI_{sb}\right) + \left(TF_b \times FI_{wb} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w}\right)\right) \times SF_f \times 10^3(g/kg)$$

$$MILK_{(g/pCi-yr)} = IR_m \times \left(\left(TF_m \times FI_m \times TF_p\right) + \left(TF_m \times FI_{sm}\right) + \left(TF_m \times FI_{wm} \times \frac{1}{\left(K_d + \sigma \times \left(\frac{S}{\rho}\right)\right)} \times \frac{1}{DF_w}\right)\right) \times SF_f \times 10^3(g/kg)$$

$$IR_s = \frac{ED_c \times IR_c + ED_a \times IR_a}{ED}$$

$$IR_i = \frac{ED_c \times IRA_c + ED_a \times IRA_a}{ED}$$

$$CR_v = \frac{ED_c \times CR_{vc} + ED_a \times CR_{va}}{ED}$$

$$CR_f = \frac{ED_c \times CR_{fc} + ED_a \times CR_{fa}}{ED}$$

$$IR_f = \frac{ED_c \times IR_{fc} + ED_a \times IR_{fa}}{ED}$$

$$IR_m = \frac{ED_c \times IR_{mc} + ED_a \times IR_{ma}}{ED}$$

$$IR_b = \frac{ED_c \times IR_{bc} + ED_a \times IR_{ba}}{ED}$$

$$IR_p = \frac{ED_c \times IR_{pc} + ED_a \times IR_{pa}}{ED}$$

1.0E-6 TR (target risk) unitless	40 t (time of exposure) yr
40 ED (exposure duration, $ED_c + ED_a$) yr	1 CPF (contaminated plant fraction) unitless
350 EF (exposure frequency day/yr	0.073 ET_o (exposure time fraction, outdoor) unitless
0.683 ET_i (exposure time fraction, indoor) unitless	0.4 DF_i (indoor dilution factor) unitless
0.9 ACF (area correction factor) unitless	0.4 GSF (gamma shielding factor) unitless
6 ED_c (exposure duration, child) yr	34 ED_a (exposure duration, adult) yr
200 IR_{sc} (child soil intake rate) mg/day	100 IR_{sa} (adult soil intake rate) mg/day
10 IRA_c (child inhalation rate) m^3/day	20 IRA_a (adult inhalation rate) m^3/day
28 CR_{vc} (child vegetable consumption rate) kg/yr dry weight	79.6 CR_{va} (adult vegetable consumption rate) kg/yr dry weight
40.2 CR_{fc} (child fruit consumption rate) kg/yr dry weight	153.1 CR_{fa} (adult fruit consumption rate) kg/yr dry weight
6.4 IR_{fc} (child fish ingestion rate) kg/yr	45.8 IR_{fa} (adult fish ingestion rate) kg/yr
4.7 IR_{bc} (child beef ingestion rate) kg/yr	50.2 IR_{ba} (adult beef ingestion rate) kg/yr
5 IR_{pc} (child poultry ingestion rate) kg/yr	35.8 IR_{pa} (adult poultry ingestion rate) kg/yr
11.77 FI_b (fodder intake for beef cattle) kg/day dry weight	0.39 FI_{sb} (beef cattle soil intake) kg/day dry weight
53 FI_{wb} (beef cattle water intake) L/day	94.1 IR_{mc} (child milk ingestion rate) kg/yr
217.9 IR_{ma} (adult milk ingestion rate) kg/yr	16.9 FI_m (fodder intake for dairy cattle) kg/day dry weight

0.41 FI_{sm} (dairy cattle soil intake) kg/day dry weight	92 FI_{wm} (dairy cattle water intake) L/day
0.3 S (fraction water content) L water/L pore space	0.5 σ (total soil porosity) L water/L pore space
1.5 ρ (soil bulk density) kg/L soil	1 DF_w (dilution factor for drinking water) unitless

NOTES:

1. SF_f=food ingestion slope factor (Risk/pCi). radionuclide-specific
2. IR_s=age-adjusted ingestion rate (mg/day).
3. TF_p=soil-to-plant transfer factor (pCi/g plant per pCi/g soil). radionuclide-specific
4. TF_b=plant-to-meat transfer factor (pCi/kg per pCi/day). radionuclide-specific
5. TF_m=plant-to-milk transfer factor (pCi/kg per pCi/day). radionuclide-specific
6. K_d=distribution coefficientr (L/kg). radionuclide-specific
7. λ = Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
8. The curie (Ci), the customary unit of activity, is equal to 3.7×10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Outdoor Worker Soil

Carcinogenic Contaminants in Soil

$$C_{(pCi/g)} = \frac{TR \times t \times \lambda^{ce}}{ED \times EF \times (1 - e^{-\lambda t}) \times \left[\left(SF_s \times IR_s \times 10^{-3}(g/mg) \right) + \left(SF_i \times IR_i \times \frac{10^3(g/kg)}{PEF} \times \left[ET_o + (ET_i \times DF_i) \right] \right) + \left(SF_e \times \frac{1}{365(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF) \right] \right) \right]}$$

1.0E-6 TR (target risk) unitless	25 t (time of exposure) yr
25 ED (exposure duration) yr	225 EF (exposure frequency) d/yr
0.333 ET_o (exposure time fraction, outdoor, 8hr/24hr) unitless	0.0 ET_i (exposure time fraction, indoor) unitless
0.4 DF_i (indoor dilution factor) unitless	0.9 ACF (area correction factor) unitless
0.4 GSF (gamma shielding factor) unitless	100 IR_s (soil intake rate) mg/day
20 IR_i (inhalation rate) m^3/day	

NOTES:

1. SF_s=adult soil ingestion slope factor (Risk/pCi). radionuclide-specific
2. SF_i=inhalation slope factor (Risk/pCi). radionuclide-specific
3. SF_e=external exposure slope factor (Risk/yr per pCi/g). radionuclide-specific
4. PEF=particulate emission factor (m^3/kg).
5. λ = Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
6. The curie (Ci), the customary unit of activity, is equal to 3.7×10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Indoor Worker Soil

Carcinogenic Contaminants in Soil

$$C_{(pCi/g)} = \frac{TR \times t \times \lambda}{ED \times EF \times (1 - e^{-\lambda t}) \times \left[\left(SF_s \times IR_s \times 10^{-3}(g/mg) \right) + \left(SF_i \times IR_i \times \frac{10^3(g/kg)}{PEF} \times \left[ET_o + (ET_i \times DF_i) \right] \right) + \left(SF_e \times \frac{1}{365(d/yr)} \times ACF \times \left[ET_o + (ET_i \times GSF) \right] \right) \right]}$$

1.0E-6 TR (target risk) unitless	25 t (time of exposure) yr
25 ED (exposure duration) yr	250 EF (exposure frequency) d/yr
0.0 ET_o (exposure time fraction, outdoor) unitless	0.333 ET_i (exposure time fraction, indoor, 8hr/24hr) unitless
0.4 DF_i (indoor dilution factor) unitless	0.9 ACF (area correction factor) unitless
0.4 GSF (gamma shielding factor) unitless	50 IR_s (soil intake rate) mg/day
20 IR_i (inhalation rate) m^3/day	

NOTES:

1. SF_s=adult soil ingestion slope factor (Risk/pCi). radionuclide-specific
2. SF_i=inhalation slope factor (Risk/pCi). radionuclide-specific
3. SF_e=external exposure slope factor (Risk/yr per pCi/g). radionuclide-specific
4. PEF=particulate emission factor (m^3/kg).
5. λ = Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
6. The curie (Ci), the customary unit of activity, is equal to 3.7×10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Tap Water

Carcinogenic Contaminants in Water

$$C_{(pCi/\ell)} = \frac{TR}{ED \times EF \times [(SF_w \times IR_w) + (SF_i \times IR_i \times K)]}$$

1.0E-6	TR (target risk) unitless	20	IR_i (inhalation rate) m^3/day
30	ED (exposure duration) yr	350	EF (exposure frequency) d/yr
0.5	K (Andelman volatilization factor) L/m^3	2	IR_w (water intake rate) L/day

NOTES:

1. SF_w=water ingestion slope factor (Risk/pCi). radionuclide-specific
2. SF_i=inhalation slope factor (Risk/pCi). radionuclide-specific
3. The curie (Ci), the customary unit of activity, is equal to 3.7×10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Fish Ingestion

Carcinogenic Contaminants in Fish

$$C_{(pCi/g)} = \frac{TR}{ED \times EF \times SF_f \times IR_f}$$

1.0E-6 TR (target risk) unitless

54 IR_f (fish intake rate) g/day

30 ED (exposure duration) yr

350 EF (exposure frequency) day/yr

NOTES:

1. SF_f=food ingestion slope factor (Risk/pCi). radionuclide-specific
2. The curie (Ci), the customary unit of activity, is equal to 3.7 x 10^{10} nuclear transformations per second. 1 picocurie (pCi) = 10^{-12} Ci. The International System (SI) unit of activity is the becquerel (1 Bq =1 nuclear transformation per second).

Soil to Ground Water

METHOD 1

Partitioning Equation for Migration to Ground Water

$$SSL_{DC} = C_w * 10^{-3} * \left(K_d + \frac{\theta_w}{\rho_b} \right) * \frac{t * \lambda}{(1 - e^{-\lambda t})}$$

20 dilution factor (used to calcualte C_w)

0.3 θ_w (water-filled soil porosity) L_{water}/L_{soil}

1.5 ρ_b (dry soil bulk density) kg/L

30 t (time of exposure) yr

The dilution factor defaults to 20 for a 0.5-acre source. If you have all of the parameters needed to calculate a dilution factor, you may use method 2.

METHOD 2

Mass-Limit Equation for Migration to Ground Water

$$SSL_{pc} = \frac{C_w * I * ED * 10^{-3} * t * \lambda}{\rho_b * d_s * (1 - e^{-\lambda t})}$$

$$DAF = 1 + \left(\frac{K * i * d}{I * L}\right)$$

where:

$$d = (0.0112 * L^2)^{0.5} + d_a * \{1 - e^{[(-L * I)/(K * i * d_a)]}\}$$

	I (Infiltration Rate) m/yr
70	ED (Exposure Duration) yr
1.5	ρ_b (dry soil bulk density) kg/L
0	d_s (average source depth) m - site-specific
30	t (time of exposure) yr
	K (aquifer hydraulic conductivity) m/yr
	i (hydraulic gradient) m/m
	L (source length parallel to ground water flow) m
	d_a (aquifer thickness) m - site-specific

For information about calculating site-specific values for the parameters included in the Mass-limit equations please refer to sections 2.6 and 2.7 of the Technical Background Document. **Do not use this method unless you have values for all of the parameters.**

Soil to Ground Water Notes

Method for Calculating Soil to Goundwater

Method 1 ◉ Method 2 ○

NOTES:

1. Screening level equations have been modified to account for radioactive decay.
2. C_w(target soil leachate concentration) (mg/L or pCi/L) = nonzero MCLG, MCL, or HBL x dilution

factor (which may be calculated or set to a site-specific default)
3. K_d (soil-water partition coefficient) L/kg = radionuclide-specific
4. λ = Decay constant (0.693/halflife) yr^{-1}. Radionuclide-specific.
5. 10^{-3} = conversion factor (kg/g)

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This page was last updated on: August 21, 2001
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